

## METAL CUTTING PROCESS

### FIELD OF THE INVENTION

5 This invention relates to the cutting of metal sheets, such as for example, steel plates used in heavy metal fabrication.

### BACKGROUND OF THE INVENTION

10 In heavy metal fabrication industries, it is often required to cut large sheets of metal, typically steel, to a given profile according to a particular design. These sheets may be too large and too heavy for convenient manipulation by hand. In the past, complex patterns were scribed, drawn in chalk or painted on the metal sheet to be cut. Personnel would then, typically, use torches to cut the desired profile as laid out. This  
15 system had a number of disadvantages, most notably the reliance on human skill both for transferring the design to the metal sheet, and in making the cut.

More recently, metal plates have been mounted on supports and moved beneath a bridge or gantry having a movable cutting head. The combination of being able to move the bridge on rolling supports in one direction, while being able to move the cutting head  
20 across the span of the bridge in a perpendicular direction permitted a profile of arbitrary planar shapes to be cut as desired. The addition of programmable control increased both the accuracy and productivity of the cutting process, and the use of a plasma arc cutting head permits the cuts to be made with higher accuracy than with a flame cutting torch.

In particular, plasma arc cutting has been used with the work piece to be cut  
25 supported on a submerged bed located in a bath. The bath is thought to absorb or reduce the noxious fumes produced in the cutting process. When the cut is finished, the liquid level in the bath is reduced to expose the parts, the cut parts are removed, and new materials are added.

30 However, while there may have been a significant investment in the cutting machinery, and in the controls used to operate the cutting machinery, the portion of the duty cycle spent in the cutting operation remained relatively low. For example, in the first step the supporting frame would be loaded with large sheets to be cut. This loading process generally involved using cranes to lift new sheets from a stock of sheets, carrying the sheets overhead, and carefully placing the new sheets to be cut in position.

Once the sheets were in position, the level of liquid in the bath was raised again to submerge the material. The cutting apparatus could then cut the sheet into the desired pieces. When finished, the cutting head would be moved to one side to give access to the various pieces. The shop personnel would then transport the cut pieces to the next  
5 production stage (or inventory, as might be), and remove the scrap. Removal of cut pieces did not tend to occur while other cutting was underway, since it might not have been prudent for personnel accidentally to provide an unintentional path to ground for the plasma arc, loading generally requires the lowering of the liquid level in the bath, and a mistake in moving material could result in shifting the remaining pieces to be cut, thus  
10 possibly yielding an incorrect profile. For these reasons it was generally only practical to remove pieces after cutting was complete.

Unloading commenced with the lowering of the level of the bath. Once all of the useful pieces and scrap had been moved away, the new stock could be brought in, and the table re-loaded. Typically, the removal of cut pieces and scrap impeded the placement of  
15 new sheets on the cutting frame such that removal had to be complete before the laying of new sheets for cutting could begin. Once loaded with new material, the level of the bath would be raised again to immerse the new sheets. All the while, during loading of new stock and unloading of cut pieces and scrap, the cutting machinery tended to be idle. By one estimate, the length of time spent loading and unloading significantly exceeded the  
20 actual time spent cutting. Although it was possible to improve production by operating two baths end-to-end, sharing a cutting head, the overall level of productivity was not necessarily entirely satisfactory. It would be advantageous to cut material more nearly continuously, and to permit at least some of the unloading of cut parts to occur in a different location, from the loading of new sheets of metal.

The baths had another disadvantage related to operation in cooler climates. Although sheltered from wind and snow, the shop was typically not heated. If the bath  
25 were left inoperative for a significant length of time, such as during Christmas shut-down, either a heating element was required to keep the bath above freezing, or anti-freeze was required, or both. Antifreeze would have to be drained, and the bath flushed before re-commencing operation. If the bath were allowed to freeze, the time and effort required to  
30 put the system back in operation was significant.

In still more recent times, plasma arc systems have been operated without using the submerged bath apparatus. Rather than using a liquid medium to absorb undesirable gases, a vacuum system is used to draw off the gases. Not using a bath system provides

the opportunity to unload and reload the work material not piece-by-piece, while the cutting heads sit idle, but rather by changing out the entire bed. That is, by having several beds, and moving them relatively quickly, the entire cutting facility can be re-loaded in a few minutes, and then loading and unloading can take place elsewhere while the material in the next bed is cut. When a non-liquid bath system is used, it is possible to move an entire bed more easily, without concerns about managing the liquid in the bath. The beds can be moved either by lifting, as with overhead gantry cranes, or by movement along a track work, such as might be laid on the floor of a bay.

In the former process, parts were removed piece-by-piece, using electromagnetic clamps to lift the cut pieces of steel. (in the case of non-magnetic materials magnetic lifting is not appropriate, in which case other lifting techniques, such as suction systems can be used in some instances). It would be advantageous to lift all the pieces off the bed at once, or in a relatively small number (two or three) of lifts, then to carry them away with an overhead crane, or to lay them on pallets where other equipment, such as forklifts and tractors, can sort and transport the cut parts as need be. It is similarly advantageous to be able to re-load the beds in a position away from the cutting head, or heads. By doing this, a vacant bed can more quickly be made ready for another cutting operation.

Use of a bath to submerge the material to be cut tended also to impose practical limitations on the size of pieces that could be cut. Part size was limited by the bath size. When a particularly large panel was desired a number of individual plates would have to be cut, aligned, and butt-welded together. For example, a number of different types of rail road cars employ side walls that are of the order of 60 ft in length, and up to about 11 feet in width from side sill to top chord. An example of such a car is a grain car or a plastic pellet car. These sidewalls have generally been fabricated by joining a plurality of plates together. It would be advantageous to be able to accept sheet from the rolling mill in a sufficient length and width to be able to cut these side walls from a single sheet, thereby eliminating the fabrication involved in butt-welding a number of plates together. Such a method of fabrication would tend to reduce defects in the resultant car structure, would tend to reduce tolerance build-up in the overall assembly, and generally facilitate assembly of the cars.

At present, long steel sheet, such as would be required to make a single piece side sheet of 60 ft length is available in coils from the rolling mill. To process the sheet directly, the coils require uncoiling. Consequently, it would be advantageous to provide a de-coiling facility adjacent to the cutting facility. It would also be advantageous to be

able to load the uncoiled sheet directly into a cutting bed, and then move the bed into position for cutting.

## SUMMARY OF THE INVENTION

5 The invention relates to an apparatus for cutting sheet metal, in which there is a cutting head that is operable to cut profiles in two dimensions, such as an x-y plane in generally planar work pieces, such as metal sheet or plate. The apparatus also includes movable carriages, or beds, on which the work piece material is loaded. The beds are 10 movable such that once a bed is loaded, it can be relatively quickly moved into a cutting position under the cutting tool, by which it can be cut. Once cutting is complete, the first movable bed can be moved away relatively quickly, and another movable bed can take its place in the cutting position, whereby the productivity of the cutting process may tend to be enhanced by keeping the cutting head busy while the first, and other, carriages are being 15 unloaded and loaded (or re-loaded).

In one aspect of the invention there is an apparatus for the cutting of sheets of metal material. The apparatus has a first transfer carriage for supporting material to be cut, a cutting head, and a pathway along which to move the transfer carriage. The cutting head 20 and the transfer carriage are movable relative to each other to permit the cutting head to cut profiles of objects lying in a plane. The carriage is movable between a loading position clear of the cutting head, and a cutting position in which the carriage presents the material to be cut to the cutting head. The pathway has a portion along which the carriage can by-pass the cutting head.

25 In a feature of that aspect of the invention, motion of the cutting head relative to the transfer carriage is automatically controlled. In another feature of that aspect of the invention, the cutting head includes a cutting member chosen from the set of cutting members consisting of (a) a cutting torch; and (b) a plasma arc. In an additional feature, 30 the apparatus further includes a venting system operable to convey fumes from operation of the cutting member away from said apparatus. In another feature, the venting system is a vacuum system operable to draw fumes from below the cutting head.

35 In another feature, at least the cutting head and a portion of the path adjacent to the cutting head are mounted within a sheltering structure. In still another feature, at least a portion of the path is over-spanned by a movable crane, the crane being operable to

engage pieces of the sheet material. In a further feature, the path has the form of a continuous circuit. In an additional further feature, the path includes alternate branches by which more than one carriage can be conducted to a position for interaction with the cutting head. In a still further feature, the apparatus has more than one cutting head operable to cut profiles in material transported by the carriage.

In yet another feature, the path includes alternate branches, the apparatus includes more than one carriage and more than one cutting head, and the carriages can be directed to the alternate branches for engagement by more than one cutting head at a time. In still another feature, the carriage is a first carriage, and the apparatus includes at least a second carriage, and the first carriage is movable to the loading position while the second carriage is in the cutting position. In still another feature, the carriage is a first carriage, the apparatus includes at least a second carriage, and the path includes an unloading position clear of the cutting position.

In a further feature, the first carriage is movable to the unloading position while the second carriage is in the cutting position. In still another feature, the unloading position is mounted within a sheltering structure. In again another feature, the first carriage is movable between the unloading and loading positions while the first carriage is in the cutting position. In another feature, the apparatus includes a first drive train operable to move the carriage along a first axis relative to the cutting head in the cutting position. In another feature, the apparatus includes a second drive train operable to return the carriage to the loading position.

In another aspect of the invention there is a process for the manufacture of rail road car side sheets including the steps of: placing a steel sheet having a length at least half as great as the length of the rail road car on a carriage; passing the carriage to a cutting position; and employing a cutting tool to cut a portion of the profile of the rail road car in the sheet.

In an additional feature of that aspect of the invention, the step of placing is preceded by the step of de-coiling at least a portion of a coil of steel sheet, and the step of placing includes placing the sheet so uncoiled on the carriage.

In a further aspect of the invention, there is a plasma arc cutting process for cutting steel sheet the process comprising the steps of: placing a sheet of steel to be cut on

a movable carriage; moving the carriage to a cutting position; operating a plasma arc cutting tool to cut a part profile in the sheet; and moving the carriage away from the cutting tool.

5 In another feature of that aspect of the invention, the step of moving the carriage away from the cutting tool is followed by the step of moving another carriage into the cutting position, and cutting material placed on that other carriage. In another feature the step of moving the carriage away from the cutting position is followed by the step of unloading the carriage while another carriage is being cut by the cutting tool. In another feature the  
10 step of unloading the carriage occurs while a third carriage is being prepared for movement to the cutting position. In still another feature, the process includes repetitively moving the carriages through a cycle of steps of loading, cutting, and unloading. In still another feature, the process includes moving the carriages along a circuit, the circuit including at least the cutting position and a loading position.

15 In still another aspect of the invention, there is a plasma arc cutting apparatus including: a plasma arc cutting head, the head being mounted to move in two directions to permits the cutting head to cut profiles in a stationary planar workpiece; and a movable bed for supporting a planar workpiece. The movable bed is movable to a cutting position  
20 in which the cutting head is operable to cut the work piece, and the movable bed is operable to transport the workpiece away from the cutting head when cutting of the workpiece has ceased.

25 In another feature of that aspect of the invention, the apparatus includes a plurality of movable beds, a first of the movable beds being movable to occupy the cutting position after a second of the movable beds has been moved away from the cutting position. In still another feature of that aspect of the invention, the movable beds are constrained to move in a circuit between the cutting position and a loading position.

## 30 **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 shows a schematic plan view of a factory having a plate cutting facility according to the principles of the present invention;

Figure 2 shows a schematic plan view of an alternate of the factory of Figure 1;

35 Figure 3a shows a smaller version of Figure 1 illustrating a stage in the cyclic procedure for cutting metal sheets;

Figure 3b shows a stage following the stage of Figure 3a;  
Figure 3c shows a stage following the stage of Figure 3b;  
Figure 3d shows a stage following the stage of Figure 3c;  
Figure 3e shows a stage following the stage of Figure 3d, returning to a state similar  
to that of Figure 3a;  
Figure 4 shows in perspective view of the plate cutting facility of Figure 1;  
Figure 5a shows a partial cross-section of a material transporting carriage of the plate  
cutting facility of Figure 1;  
Figure 5b shows upper and lower wear lows as employed in the carriages of Figure  
5a;  
Figure 6a shows a chassis layout schematic for secondary carriages of the plate  
cutting facility of Figure 1;  
Figure 6b shows a detail of a motor installation of a secondary carriage of Figure 6a;  
Figure 7a shows a view looking along the return portion of a transport path of the  
factory of Figure 1, indicated as '7a' on Figure 1;  
Figure 7b shows an oblique view of a transition drive train of the factory of Figure 1  
indicated as '7b' on Figure 1;  
Figure 7c shows a detail of a carriage pulling and pushing towing head of the  
secondary carriage of Figure 6a;  
Figure 8a shows a view of an exhaust manifold for the cutting facility of Figure 1  
with one exhaust manifold port open; and  
Figure 8b shows a detail of a control assembly for the exhaust manifold of Figure 8a.

## DETAILED DESCRIPTION OF THE INVENTION

The description which follows, and the embodiments described therein, are provided by way of illustration of an example, or examples of particular embodiments of the principles of the present invention. These examples are provided for the purposes of explanation, and not of limitation, of those principles and of the invention. In the description that follows, like parts are marked throughout the specification and the drawings with the same respective reference numerals.

In terms of general orientation and direction nomenclature, reference is made below to advance and return, and to transverse motion. For the purposes of this description the cutting process pertains to cutting a generally horizontally planar sheet or plate with a vertically oriented cutting tool. Relative motion between the cutting tool and

the sheet or plate is two-dimensional motion that can be described in terms of components lying along two axes in a horizontal plane. For the purposes of this description those axes will arbitrarily be given the nomenclature of **x** and **y** axes, the **x**, or longitudinal, axis lying in the direction of advance or return of the sheet or plate, and the **y**, or transverse, axis lying perpendicular to the **x** axis.

In Figure 1, a manufacturing facility is indicated generally as **20**. It includes a sheltering structure in the nature of a factory building or shop **22** that has a yard **24** having an accessway, such as a road **23** or rail siding **25** by which raw stock materials can enter the plant and finished products may be shipped to market. Shop **22** includes a bay **26** in which a metal cutting apparatus in the nature of a multi-head plasma-arc cutting facility **28** is located.

Cutting facility **28** includes a longitudinally movable spanning member, termed a burn carriage, or bridge **30** located to straddle a pathway, or track, of a material transport apparatus or, transfer system **32**, described more fully below. Bridge **30** is mounted on wheels **34** at either end, wheels **34** being mounted on a pair of parallel ways **36**, **37** to permit travel in the **x** direction. Bridge **30** has an electric geared drive **38** that is operable in co-operation with toothed racks adjacent to ways **36**, **37** to move bridge **30** longitudinally with a level of precision appropriate for cutting a profile in the work-piece material. Cutting facility **28** includes four plasma-arc cutting heads **40**, **41**, **42** and **43**, all mounted to bridge **30**, and each being operable to move along the span (that is, in the **y**-direction) of bridge **30** to permit cutting of objects located beneath bridge **30** as required. In addition to **x-y** motion the cutting heads can also be tilted to produce a bevelled, or chamfered edge. Cutting facility **28** is controlled numerically by a computer **46** mounted beside the operator console **44** the cutting heads **40** to **43** being employed to cut profiles in sheets of material according to design information fed into a computer **46**.

Transfer system **32**, follows a path, indicated generally as **48**, in the form of a rectangular continuous loop, or circuit. Path **48** has a first portion **50** running in the longitudinal, or **x** direction. Moving frames, or carriages, indicated as items **52**, **54**, **56**, **58**, and **60** are provided to transport sheets of material to be cut in an advancing direction, as generally indicated by arrow 'A' (parallel to the **x**-axis). The carriages convey the sheets or plates to a cutting range, or cutting zone (namely the burn position indicated generally by arrow 'B'), where the sheets are cut according to chosen design profiles input to computer **46**. Transfer system **32** includes a second, or return, portion **64** by which carriages from the



output side of cutting facility 28 can bypass cutting heads 40 to 43 and be returned back to the input side of cutting facility 28.

Transfer system 32, in addition to advance portion 50, and return portion 64, includes a first, or input, lateral transfer portion 66 by which carriages can be moved on secondary carriages in the nature of a lateral transfer cart, or shuttle 68, that is movable along transverse portion 66 in the transverse, or y direction on a between return portion 64 and advance portion 50 on the input side of cutting facility 28. Transfer system 32 also includes a second, or output, lateral transfer portion 70, also running in the y-direction, across which the carriages can be moved on another secondary carriages in the nature of a second lateral transfer cart, or shuttle 72, that is movable along transverse portions 70 in the transverse, or y direction, between advance portion 50 and return portion 64 on the output side of cutting facility 28.

Transfer shuttles 68 and 72 are wider in the x direction than carriages 52, 54, 56, 58, and 60 are long, and have first and second ways 74, 76 spaced to match the ways upon which those carriages travel in advance portion 50 and return portion 64. When shuttle 68, or 72, is aligned with advance portion 50, a carriage, such as carriage 52 or 54, can be advanced from portion 50 and onto ways 74, 76 of shuttle 72. When carriage 52 is thus positioned, shuttle 72 can be moved transversely (in the +y-direction, until aligned with the ways 78 of return portion 64. When aligned, carriage 52 or 54 can be urged backwards, that is, in the return or -x direction, out of shuttle 72. In the illustrations of Figures 1, 2 and 3a to 3e the size of carriages 68 (and 72) is exaggerated relative to carriages 52 – 60 for the purposes of clarity of conceptual explanation.

In the embodiment illustrated in Figure 1, transfer system 32 includes a loading zone (indicated generally by arrow 'C') adjacent to the return portion 64 lying generally to the input side of cutting zone 'B'. Similarly transfer system 32 has an unloading zone, indicated generally by arrow 'D', adjacent to return portion 64. In the general course of operation, the carriages are loaded with new stock at loading zone 'C', moved across input transfer portion 66 on shuttle 68, and advanced along portion 50 in the direction of arrow 'A' to a cutting position in cutting zone 'B'.

When in the cutting position, also called the "burn position", the particular carriage is, or carriages are, temporarily locked in position against stops mounted in a fixed, known reference position. The first stops 80, 81 have the form of retractable electrically grounded

posts having an electrically conductive platen facing whichever of the carriages is located in the adjacent burn position. Stops **80, 81** can be lowered when it is desired to move carriages with cut materials out of the burn position. At the far end of the carriages, retractable clamping members **82** and **83** are raised to bear against the opposite end of the respective carriages, (such as **52, 54**) and tightened, thus squeezing the carriages between themselves and stops **80** and **81** respectively, and fixing them in a known datum location relative to bridge **30**. Clamping members **80** and **81** also employ electrically conductive, and electrically grounded platens such that the clamping process also serves to provide an electrical path from the carriage through which the plasma arc current can find ground either through stops **80, 81** or through clamping members **82, 83** or both. Once the carriage is, or carriages are, locked in position, bridge **30** and cutting heads **40 – 43** are moved co-operatively in the x and y directions to produce the desired profiles.

After the various items have been cut, the carriages are (or carriage is) unlocked by releasing clamping members **82, 83**, and lowering stops **80, 81**. The carriages can then continue along advancing portion **50** and onto output lateral transfer shuttle **72** until in position to be transferred laterally to return portion **64**. Once advanced, or, alternatively at the same time as they are being advanced, another carriage (or pair of carriages) such as carriages **56** and **58** can be advanced into the burn position for cutting. While the next set of plates is being cut, the first carriage is moved to the unloading position in unloading zone 'D'. Once the cut parts are unloaded, the carriages, bearing only the scrap, are returned to loading zone 'C' along return portion **64** where the scrap is removed and new material loaded. The various carriages can continue around the circuit in a continuous loop as long as there is material to be cut.

For the purposes of loading and unloading, manufacturing facility **20** is provided with an inside overhead crane, **86** mounted to run along rails **86, 89** mounted to building columns **90** inside shop **22**. Crane **86** is moveable to overspan unloading area 'D' and adjacent work areas 'E' and 'F'. Alternatively, internal roadways **G** and **H** provide access by forklift such that materials in the unloading bay can be despatched to other areas of the plant. Manufacturing facility **20** is also provided with an external overhead crane **92** running in the y direction along rails **94, 95** mounted to pillars **96**. Crane **92** is movable over a range covering loading area 'C', inventory area 'J' and first transfer shuttle **68**. This arrangement permits loading of carriages mounted in first transfer shuttle **68** either when in a position most closely adjacent to inventory area 'J' or when moved further away, as for example,

when aligned with first portion **50** and awaiting advancement in the x-direction to the burn position.

5 This arrangement may tend to permit operation of the cutting heads to continue while finished pieces are being unloaded and new stock is being loaded, thereby tending to improve utilization of the cutting heads. It also permits unloading of finished pieces from one carriage to occur while new stock is being loaded on another carriage.

10 In the embodiment shown in Figure 1, first portion **50** of transfer system **32** includes first and second parallel branches **100** and **102**, such that loaded carriages can advance along either branch, as selected, and, advantageously, two carriages can be in the cutting zone at one time such that cutting heads **40** – **43** can operate on more than one work piece at a time. The infed area, indicated generally as **K** on the input side of cutting facility **22** is sufficiently large to accommodate a pair of waiting carriages side-by-side while another pair of carriages is in the cutting zone. In general, it is intended that two carriages be unloaded and re-loaded one after the other while two other carriages are in the cutting zone being cut side-by-side.

15 It is not necessary that two carriages be cut at the same time, and it is not necessary that carriages always be in all of the cutting, loading, and unloading stations at the same time. While the five carriage arrangement illustrated in Figure 1 is preferred for a circuit having a single track return portion, such as portion **64** the system can be operated with fewer carriages, or more, according to the space available. It may be that one carriage is loaded with material to be cut into a large number of small pieces, implying a relatively long cutting time, while another carriage has only a single large piece, or a few large pieces. In that case the double branch arrangement permits the faster cut carriage to be changed out, and another carriage put in its place, while the slower carriage remains in the burn position. Alternatively, operations can be carried out with a single carriage, but would generally be more effective if at least first and second carriages were used.

20 It is not necessary that the transfer system include a pair of branches in the cutting zone. It could include a single unique path, or more than two paths according to the number of cutting heads available. Similarly, there need not be a single, unique return portion, but rather, as in Figure 2, a system **110** could be provided having a double track return portion  
25 **112**. In the case of the embodiment of Figure 2, it would be advantageous to use six carriages **52**, **54**, **56**, **58**, **60** and **114**, given the ability to unload two carriages side-by-side.

It is not necessary that transfer system 32 be formed in a rectangular shape, with four separate drives each operable to urge the carriages along one side of the rectangle. For example, a triangle or other polygon shape, or an oval with large turn radii could be used. However, the rectangular arrangement is preferred since it does not require additional space for turn radii, does not require curved track to be laid, and does not require the carriages to be turned during operation. Rather, as described, the rotational orientation of the carriages in the horizontal plane remains constant throughout the processing operation.

The sheet material to be cut by the apparatus of Figure 1 or Figure 2 is most typically steel sheet or steel plate that is substantially planar. That is, it is material of some thickness for which the cutting heads will trace out a profile defined in terms of a two dimensional plot defined by relative motion of the cutting heads and the work piece, (or pieces) along of x and y axes, where the x axis lies in the direction of advance along the ways of the first portion of track system 28, (and, parallel to the line of motion of return portion 64), and the y axis is the span direction of the bridge of cutting facility 28 along which cutting heads 40 to 43 run.

The steel sheets, or plates that can be transported on the carriages can be of significant size, according to the width and length of the carriage. In the preferred embodiment the carriage width permits plates up to 11 ft.- 4 in. wide and 64 ft. - 10 in. long and up to about 2 inches thick to be cut. That is, the carriage size significantly exceeds a 30 foot or 40 foot length, giving greater versatility in the size of parts that can be cut. Plates of this size are generally well beyond a size that might otherwise be manipulated by hand. Larger tables can be made to permit the cutting of larger plates. In an additional, optional feature, as shown in Figure 1 and Figure 2, a de-coiler 120 is provided between loading area 'C' and an adjacent rail siding 25. Crane 122 is located in a position to lift coils from rail road cars running on siding 25 into de-coiler 120. In operation the output from de-coiler 120 is fed directly onto a waiting carriage, such as carriage 56 mounted on shuttle 68. Shuttle 68 is then moved to a position to allow another un-coiled sheet or other material from stock to be loaded on an adjacent carriage, such as carriage 58 and transferred to a position to be moved to the burn position.

#### Operation of the Embodiment of Figure 1

The sequence of operation of the cutting and transporting apparatus of Figure 1 is shown in Figures 3a to 3e. To commence, as shown in Figure 3a, carriages 52 and 54 are in

the first and second slots in the burn position, respectively. Carriages **54** and **56** are in the corresponding first and second positions of first shuttle **100**, and carriage **60** is in the unloading position on return portion **64**. When the cutting of the pieces is finished on carriages **52** and **54**, they are advanced onto the output transverse shuttle **72**, and carriages **56** and **58** are advanced into the burn position, as shown in Figure **3b**. Cutting commences on carriages **56** and **58**. Shuttle **72** is moved in the +y direction to align rails **124** with the rails **126** of return portion **64**. Unloading of carriage **60** is either complete, or being completed.

As shown in Figure **3c**, shuttle **72** is moved further in the y direction to a position in which its second slot, or second pair of rails, **128** is aligned with rails **126** of return portion **54**. Carriage **60**, now unloaded, is moved onto rails **130** the second slot, or both of shuttle **68**, and, once any remaining scrap has been removed (typically, to be recycled), loading commences either from stock or from de-coiler **120**, with the aid of overhead gantry crane **92** as may be required. Shuttle **72** can be moved in the +y direction to align the rails **124** of its second carriage slot or both **132** with the rails **126** of return portion **64** either before, during, or after carriage **60** has been moved to shuttle **68**, although it is preferable for both tasks to be performed simultaneously such that rails **126** of portion **64** are clear when carriage **52** lines up with them. In that case there need be little or no delay in moving carriage **52** from shuttle **72** to rails **126**. While unloading commences from carriage **52**, cutting continues on carriages **56** and **58**.

As shown in Figure **3d**, carriage **60** has been moved with shuttle **68** in the -y direction to align the first set of rails **134** of shuttle **68** with the rails of return portion **64**, and carriage **52**, now unloaded, has been moved in the -x direction into the awaiting first, carriage slot, or berth of shuttle **68**. Unloading of any remaining scrap is completed, and then loading of new material commenced, either from the stock of plates, or from coils passed through de-coiler **120**. Shuttle **72** has been moved in the +y direction to align its second slot, or berth **138**, with rails **126** of return portion **64**, and carriage **54** is moved in the -x direction onto rails **126** of portion **64** for unloading. As above, the alignment of the second slot can take place before, during, or after movement of carriage **52** onto shuttle **126**, but is preferably complete soon enough to permit carriage **54** to be moved as soon as rails **126** are no longer occupied by carriage **52**. Unloading in zone 'C' commences. Cutting continues on carriages **56** and **68**.

In Figure 3e, the situation is similar to that of Figure 3a. Cutting on carriages 56 and 58 is nearly complete. Shuttle 72 has been moved in the -y direction to position its slots, or berths, in a position to await loading of two carriages transporting freshly cut material, namely carriages 56 and 58. Shuttle 68 has been moved in the -y direction to align its rails with those of branches 70 and 72 of portion 50. As in Figure 3a, a further two loaded carriages, namely carriages 60 and 52, are positioned in the slots, or berths, of shuttle 68, awaiting their turn to advance to the burn position as soon as the slots of the burn position are vacated by carriages 56 and 58. Carriage 54 is in the process of being unloaded.

In the example illustrated, the cut parts, 140, have the profiles of grain hopper car side sheets, cut in one piece. In the more general case, as also indicated by the several items 142 in Figure 3a, this cut profile of parts 145 is intended to represent the cutting of profiles of a number of parts, from one large part to several parts of smaller size, whether being a batch of parts of one type, or a mixture of parts of different sizes.

#### Operation of the Embodiment of Figure 2

The embodiment of Figure 2, as noted above, differs from that of Figure 1 in having a pair of side by side return portion rails 144 and 146. In this instance shuttles 68 and 72 do not have to shuffle between positions for transferring carriages in sequence either to or from a single track, such as rails 126 of portion 64. Rather, carriages 68 and 72 move to a single load/unload position, and both carriages can be, and preferably are loaded and unloaded at one time, side-by-side.

That is, while two carriages 52, 54 are in the burn position, another pair of carriages 60, 114 is moved on shuttle 72 to a position for being transferred in the -x direction onto the return rails 144, 146 of double branch return position 148, 72. When this action is complete, shuttle will reverse and take up its former waiting position opposite the ends of rails 150, 152 of the burn position. At the same time the third pair of carriages 56, 58 is being prepared (i.e., emptied of scrap, re-loaded with new material, and transferred into an aligned position) on the other shuttle. These activities could be performed in sequence, rather than simultaneously, but simultaneous preparation, loading and unloading may tend to improve overall productivity.

The system of Figure 2 retains the capability to load one car at a time in series (rather than parallel), or to use only one input or output track, either to transfer carriages between

sides of the loop or to reflect different cutting speeds according to the cuts required per carriage. However, in general the two carriage, side-by-side mode is considered advantageous for higher overall productivity for the embodiment of Figure 2. The arrangement of Figure 2 may tend to require greater floor space than that of Figure 1.

### Description of Carriages

In the embodiments of Figures 1 and 2, carriages **52, 54, 56, 58** and **60** (and **114**) are rolling frameworks positioned to support the sheets, or plates, to be cut some distance above the floor of the bay. Carriages **52, 54, 56, 58, 60**, and **114** are all of the same construction. They each have a pair of first and second longitudinally extending left and right hand side frames **160** and **162**. Each side frame **160, 162** has a pair of back-to-back, spaced apart channels **164, 166**. The channels are maintained in spaced apart parallel relationship by intermittently spaced gusset plates **185, 187**. Flanged fore and aft wheels **188, 190** are mounted between channels **184, 186** in a position in which their motion is constrained to follow, that is, is guided by the rails running in the x direction. The gauge, or track spacing, of the rails of first portion **50**, second portion **64**, and the rails of the carriage berths of shuttles **68** and **72** are all the same, and the spacing of side frames **160, 162** is such as to yield the same spacing for wheels **168** and **170**. Inclined slag deflector skirt plates **189** are mounted on the inboard face of inboard channel **186** to discourage accumulation of slag on the rails, and to encourage the slag to collect in the slag pans **300**.

Each of the carriages also includes fore and aft, horizontally extending end frame members, **172, 174** welded across the ends of longitudinal side frames **160, 162**. End frame members **172, 174** are formed from sections of channel, and co-operate with side frames **160, 162** to define the basic rectangular form of the carriages. The top flange of side frames **160, 162** and the top flange of end frames **172, 174** all lie in a common plane. A series of mounting brackets **176** are spaced along the upper flange of the inner channel member of each of side frames **160** and **162**, and a pair of cap angles **178, 180** are bolted to brackets **176**, with one toe extending downward, and the other toe extending inward.

In Figures **5a, 5b**, each carriage has an array, or matrix, of material support members made up of lower wear bar carriers in the nature of lower stringers **182**, upper wear bar carriers in the nature of upper stringers **184**, and wear bars **186**. Lower stringers **182** are made from plate of a length corresponding to the width between the webs of the inner channel members of side frames **160, 162**, and a height corresponding to the depth of the

inner channel members. The ends, or tips, of each of lower stringers **182** are cut to a profile matching the internal profile of the inner channel member. Lower stringers **182** are made of steel and are welded in position in spaced vertical planes along side frames **160**, **162**.

Upper stringers **184** and lower stringers **182** have corresponding knife joints **188**, **190**, that is, slots, located such that at each crossing of a lower stringer by an upper stringer, a downwardly opening slot of a lower stringer aligns with an upwardly opening slot of an upper stringer to permit the upper and lower stringers to slide together vertically, forming a cross-hatched matrix. Upper stringers **184** are not welded in place and can be lifted out for replacement as required. Given the pitch of lower stringers **182**, the length of upper stringers **184** is such that each upper stringer spans four gaps, or pitches, between lower stringers **182**, with the ends notched to overhang. The next adjacent upper stringer is also notched such that the two longitudinally adjacent upper stringers overlap the last joint. The upper stringers are also made from mild steel, and are electrically conductive. The upper edge of each upper stringer **184** is also notched with slots or knife joints **192** for receiving the horizontally extending wear bars **186**.

Wear bars **186** are made of flat bar of a length spanning the carriage between cap angles **178**, **180**, and of a thickness corresponding to the thickness of the slots, knife joints **192** in the upper edges of upper stringers **184**. Wear bars **186** are made of mild steel, are electrically conductive, and are not provided with notches. Cap angles **178**, **180** serve to prevent wear bars **186**, upper stringers **184** and lower stringers **182** from being lifted out when electro-magnets are used to remove work pieces or scrap from the carriage. Inclined baffles **194** are mounted longitudinally between lower stringers **182** to encourage slag to fall into slag pans **300**, and function to discourage slag from clogging the dampers **286** of the exhaust system.

Wear bars **186**, upper stringers **184** and lower stringers **182** are all electrically conductive, and provide multiple paths by which the plasma arc current can reach ground through the side frames and end frames into the grounded platens of stop **80** (or **81**) and clamp clamping member **82** (or **83**).

Each of wear bars **186** is a steel bar made from a 11' - 4" long, 4" x ¼" flat bar (+/-) set on edge, each flat bar having a length of about 11' - 8" to span the corresponding distance between the webs of the inner channels of end frames **82** and **84**. There are **99** wear bars **186** spaced along the length of each carriage, that length being about 64' - 10". This



array of parallel bars provides a matrix upon which work-pieces to be cut can be supported. Wear bars **186** are consumable items. That is, when plasma arc cutting occurs, the arc may tend to cut to a depth exceeding the thickness of the materials to be cut, and may notch the upper edge of the wear bars at the locations at which the desired profile of the cut crosses each wear bar. The wear bars also tend to become encrusted with slag. When the wear bars have been used several times they can be changed out for new, unworn bars. When the upper edges of the backing bars have been cut many times in this way, such that they may no longer provide enough points of support to reliably support the work pieces in the desired horizontal plane, they are replaced.

As noted above, the carriages are constrained to follow the fore-and-aft rails. To this end, each end frame of each carriage has a drive force interface member in the nature of a towing lug **198** for engagement by a drive hook, as described below.

#### Description of Shuttles

Shuttles **68** and **72** also have the same construction. Referring particularly to Figures **6a** and **6b**, each has a rectangular steel ladder frame having side frames in the nature of wide flanged beams **200**, **201**, intermediate longitudinal beams **202**, **203** and lateral beams **204**, **205**, **206** and **207** that pass through the webs of side frames **200**, **201** and intermediate beams **202**, **203**. A running rail **210**, is mounted to the top flange of each of beams **200**, **201** and **202**, **203**, the pairs **200**, **202** and **201**, **203** each being spaced a suitable distance to correspond to the spacing of the pairs of rails of portion **50** or portion **64**. Intermediate transverse brace members **212** extend between members **200**, **201**, **202** and **203** between the locations of lateral beams **204**, **205**, **206** and **207**. A longitudinal chain drive is mounted mid-way between beams **200** and **202**, **201** and **203**. Lateral beams **204**, **205**, **206** and **207** are each made of a pair of back-to-back channels, spaced apart with gussets. Diagonal braces **218** tend to assist in keeping shuttle **68** (or **72**) square.

At the ends of each of lateral beams **204**, **205**, **206** and **207** are flanged wheels **208**, **209** mounted between the channels of beams **204**, **205**, **206** and **207** to roll along rails **220**, **222**, **224** and **226** mounted in recessed channels in the floor of bay **26**. As noted, rails **220** to **226** extend in the transverse, or y-direction, and permit the shuttle (**68** or **72**) to move between positions aligned with portions **50** and **64**. Electric motors **230** and gear boxes **232** are mounted to one end of each of the foremost and aftmost beams **204** and **207**, and operation of these motors and gearboxes will tend to urge the shuttle in either to +y or -y

direction as may be appropriate according to the stages of the cycle. Stops are provided at the ends of rails **220** and **226** to prevent overtravel. An operator's platform, or cab, **234** is mounted at the far end of shuttle **68**, or **72**, from which operation of the shuttles is controlled. Lateral beams **204**, **205**, **206** and **207** are each made of a pair of back-to-back channel sections, spaced apart with gussets.

### Description of Carriage Drives

Referring to Figures **7a**, **7b** and **7c**, as noted above, each of shuttles **68** and **72** has a pair of motorized chain drives, **228** operable either with a ram head to push against the abutment plate of the towing lug to force the carriage out of the particular berth of the shuttle, or a hook operable to engage the endplate of the towing lug **198** so that each carriage can be drawn into place on the shuttle as required. In addition, return portion **64** has a chain drive **234** that is operable to urge carriages out of the unloading zone toward the re-loading zone, and a pair of short chain drives **236** and **238** are used to push carriages from the end of the push stroke of carriage **68** to the burn position. That is, drives **236** and **238** are used to push carriages, such as carriages **52** and **54**, over the threshold of the doorway of bay **26**, and the last few feet past the doorway into the burn position. These chain drives have the same features and differ only in length or in the type of tow head employed. In that light, enumeration of the drive components of one chain drive, **240**, are to be taken as being representative of all of the chain drives, except as specifically indicated.

Each chain drive **240** includes a guide rail assembly **242**, along which a motion transmission member, such as towing head **244** of shuttle **72**, runs. Towing head **244**, (or such other towing head or pusher may be used), is attached to both ends of a chain **246**, that is carried over an idler **248** at one end of guide rail assembly **242**, and a driven pinion **250** at the other. Driven pinion **250** is itself mounted on a stub shaft **252** that is driven by an electric motor **254** through a transmission chain **256** and an input gear **258**. All of the elements of chain drive **240** are mounted to the lateral beams **204** to **207** and the transverse braces **212**, **214** and **216** of the chassis of shuttle **68** (or **72**, as may be).

Towing head **244** is of the type used on shuttle **72**. Towing head **244** includes a pushing member in the nature of a prong **260** whose distal end can be positioned to bear against the end plate **196** of towing lug **198** of each of the carriages, as when it is desired to move one of the carriages from shuttle **72** to rails **126** of portion **64**. Towing head **244** also has a long hook **245** that is swung into place across the walkway to catch on the chamfered

upward lip of end plate **196** of towing lug **198**. When attached in this way, operation of the chain drive of shuttle **72** in the +x direction will cause towing head **244** for draw a carriage onto shuttle **72**.

5           The towing head of the chain drive of shuttle **68**, does not have the long hook, but rather employs short retractable hook **262**. When either of the chain drives of shuttle **68** is driven in one direction, it will tend to force prong **260** to move in the positive x direction, thus urging any carriage carried on shuttle **68** in the +x direction into the burn position. When towing head **244** is in the pushing mode, hook **262** is in the retracted position.  
10          However, when it is desired to draw a carriage from the unloading position on rails **126** of portion **64** onto carriage **168**, as for removal of scrap and re-loading, hook **262** is moved, i.e., pivotted, to a deployed position to engage the eyelet of towing lug **198**, by which the particular carriage can be towed. Prong **260** has a sufficient reach to push the carriage to the point at which it can be moved with one or other of chain drives **236** or **238** past the door  
15          threshold, and into the burn position.

          Chain drives **234**, **236** and **238** employ pushers **249** in place of towing head **244**. Pusher **249** is biased by a spring to a raised position. In the raised position the head of pusher **249** bears against the end frame of the carriage, whichever it may be, and, when driven, urges the carriage along whichever set of rails it is running on. However, when it is desired to return pusher **249** to its start position, or when it is desired to allow a carriage to pass over pusher **249**, the spring allows pusher **249** to deflect pivotally, such that the head of pusher **249** moves downward, and forward in the direction of advance of the particular chain drive. Once the object has passed overhead, pusher **249** resumes its raised position. In  
20          summary, the operation of chain drives **228** mounted to shuttles **68** or **72**, or chain drives **234**, **236** or **238**, in the x direction, and the movement of shuttles **68** and **72** in the y direction permits the various carriages to be urged around the circuit of path **48** between loading (or re-loading), cutting, and unloading positions.

30           When a carriage is being loaded into the burn position, clamping member **82** (or **83**) lies in a retracted, or 'down' position shy of the profile of rails **280** of portion **50**, such that it is clear of whichever of the carriages may next pass overhead. When the carriage is in position against stop **80** (or **81**) as the case may be, clamping member **82** (or **83**) is pivotted about a longitudinal axis to an upright position. Once in the upright position, the electrically conductive platen of clamping member **82** (or **83**) is tightened against the end frame of the carriage, as described above, and cutting can commence. When cutting is complete,  
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clamping member **82** (or **83**) is released, and pivoted back to a the lowered position to clear the pathway for the next carriage.

### Description of Venting System

When the plasma arc cutting heads are in operation, a quantity of noxious gases and fumes is produced. The raising of the work piece plates clear of the floor on top of the carriages, which are carried on rails **280**, mounted on support beams **281**, permits the installation of a ventilating, or gas extraction apparatus in the nature of a vacuum system **156** whose intakes draw from the region below the plates under the location of the cutting heads. The gases and suspended particles so removed may then be filtered and treated as may be required at an external settling device, such as a cyclone or scrubber.

In Winter operation, the vertically moving end doors **277** of the bay are raised only far enough to admit entry or exit of the carriages, each of the end doors being provided with movable skirt sheets **279**, of either rubber or plastic, that hang across the opening, and are deflected by the movement of the carriages. The skirt sheets fall back into place when the carriages are clear. Fresh air is supplied to the bay by the ventilating fans of the building generally (not shown).

Referring to Figures **1**, **8a** and **8b**, the venting system includes an external dust cyclone assembly, indicated as **270**, mounted outside of doors **272**, out of the way of movement of shuttle **68**. Dust cyclone assembly **270** can include particle filtering elements, a liquid scrubbing element, whether of the water curtain of water bath type, or an electrostatic type of scrubber, as may be found suitable for the operating conditions of the plant more generally. In any case dust cyclone assembly **270** includes a cyclone for settling out solid particles, and a blower operable to draw air, noxious gases, and fumes through the venting system generally. In the preferred embodiment the venting system includes three cyclones and three blowers operating in parallel, although a greater or lesser number can be used depending on system design point – that is, at the combination of a desired volumetric flow rate, and the corresponding pressure drop through the system at the desired flowrate.

Dust cyclone assembly **270** is fed by through a common feed duct **274** drawing from a pair of first and second inflow manifolds **276** and **278**. Feed duct **274** is routed to pass below rails **280** of portion **50**. Rails **280** of portion **50** are raised on longitudinal beams to match the height of the rails of shuttles **68** and **72**. This height also gives a clearance space

in which to run ducting or to place boxes for the collection of slag. Inflow manifolds **276** and **278** each have the form of a rectangular duct, or trunk **282**, extending in the x-direction midway between each of the respective pairs of rails of the first and second berths, or slots, of the cutting position 'B'. That is, when carriages, such as carriages **52** and **54** are in the burn position, and cutting is underway, inflow manifolds **278** lies under carriage **52**, and inflow manifold **524** lies beneath carriage **54**.

In each case trunk **282** has a series of ports **284** formed in its upper wall, each of the ports having a closure member or door, or damper, **286** movable between an open position in which gases can flow into trunk **282**, and a closed position in which flow is impeded. Each of dampers **286** is controlled by a pneumatic actuator **288**. Each of actuators **288** is operable in response to a pneumatic signal carried from a pneumatic switch valve **290** mounted adjacent to the running rails of burn carriage, namely bridge **30**. Each pneumatic switch valve is actuated by pressing downwardly on an upwardly biased valve actuator, in the nature of a spring loaded cam follower. The cam follower in this instance is a roller **292**. The pneumatic switch valves of manifold **278** are aligned in a first row extending in the longitudinal, x, direction, and the pneumatic switch valves of inflow manifold **276** are aligned in a second longitudinal row, offset from the row of the switch valves of inflow manifold **278**.

The burn carriage **30** has a shoe **294** mounted at one end thereof. Shoe **294** is operable to control the position of valves **290** as burn carriage **30** travels in the x direction. Shoe **294** has two downwardly facing cams, one for the switching valves of inflow manifold **278**, and the other for the inflow valves of manifold **278**. Shoe **294** can be raised pneumatically to run completely clear of switch valves **290**, such as where burn carriage **30** is running to a disengaged position without any of the plasma arc cutting heads in operation. The cams of shoe **294** can also be lowered so that it operates each one of switching valves **290** as they are encountered in turn. In a further alternative, where cutting is occurring on only one carriage, shoe **294** can be positioned to engage the switching valves **290** of only one of inflow manifold **278** or inflow manifold **278**, so that cases are drawn only from under the carriage subject to cutting.

As the burn carriage moves, the cams engage the cam followers, causing the dampers of the ports most closely adjacent to the cutting operation to open, and to remain open while cutting is in that vicinity. When the cutting heads move away, those dampers close, and the next adjacent dampers open. In this way, the opening in the manifold moves,

in effect, to follow the cutting heads as the burn carriage moves longitudinally. At any time at least one damper **286** is open, and in transition, two dampers are relatively briefly open together. As a result, venting system provides a sink, or low pressure area, adjacent to the cutting heads toward which gases and fumes tend to be drawn. Inasmuch as the matrix of lower strings **182**, upper stringers **184** and wear bars **186** provides a plurality of vertical pathways for gas to be drawn downwardly, and given that the work-piece material tends to form a barrier to passage of the air downwards, the area under the matrix of stringers will itself tend to act as a plenum, the gas and fumes most close to the open port of the inflow manifold will tend to be most strongly urged toward the manifold, when they can be exhausted from the bay.

To either side of either inflow manifold **276** or **278**, between the vertical side walls of trunk **282**, and the adjacent rails **280** there is a space into which, in the general course of cutting, undesirable materials may tend to collect, such as blanks cut from the work pieces, slag, soot, and so on. To facilitate removal of this unwanted material, slag boxes, or slag pans **300** are placed in close fitting positions between trunk **282** and each of the rails to either side. Each slag box has four upright sides assembled to form the peripheral walls of a rectangular box, and a base, forming the bottom of the box. Each box also has a pair of lateral internal partitions, typically dividing the box in three roughly equal portions. The partitions are provided with lifting holes, such that when the boxes approach full, they can be lifted out by crane and replaced.

Various embodiments of the invention have now been described in detail. Since changes in and or additions to the above-described embodiments may be made without departing from the nature, spirit or scope of the invention, the invention is not to be limited to those specific embodiments.